

# *Management Summary*

UCRL-AR-122292 Rev 1

Environmental Restoration  
at  
Lawrence Livermore National Laboratory  
Site 300  
Livermore, California



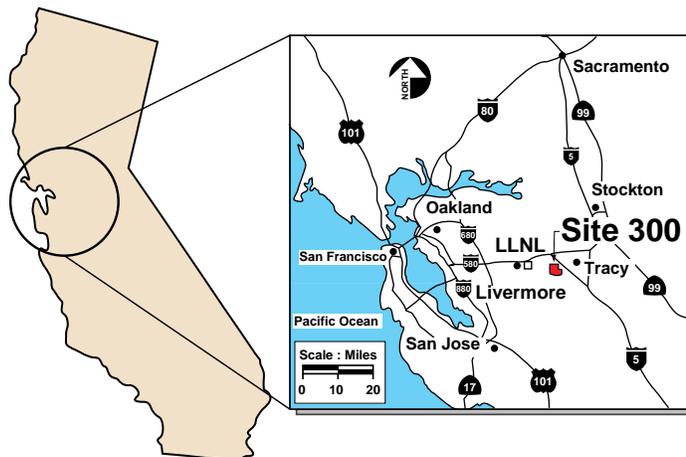
**U.S. Department of Energy**

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# Management Summary

This report summarizes the status of Environmental Restoration (ER) activities at Lawrence Livermore National Laboratory (LLNL) Site 300. Site 300 is a remote experimental test facility located in the rugged Altamont Hills east of Livermore, California. Past defense program activities have resulted in releases of contaminants to the subsurface at about 30 locations. These contaminants include volatile organic compounds (VOCs), radionuclides, high explosive (HE) compounds, nitrate, metals, polychlorinated biphenyls (PCBs), and fuel hydrocarbons. Eight operable units, or OUs, have been defined at the site. Since 1981, significant progress has been made to clean up contaminated soil and ground water. The U.S. Department of Energy (DOE) employs landfill capping, excavation, ground water interceptor trenches, soil vapor and ground water extraction, bioremediation, and innovative technologies to accomplish cleanup objectives. Removal actions are used to accelerate remediation projects. DOE recently received regulatory approval to implement low-volume purging prior to monitor well sampling, which will result in significant cost savings. LLNL ER staff have developed an extensive web-based data access and display system, greatly facilitating interpretation of analytical and hydrogeologic information. Site 300 is commonly used as an environmental technology test bed for DOE, academic, and private research. Two individual OU Records of Decision (RODs) are in place, a third is scheduled for 2001, and a sitewide ROD is expected in the year 2000.



## SITE CHARACTERISTICS

### Site History/Release Characteristics

Site 300 was established in 1955 as research and development laboratory owned by the DOE and operated by the University of California. Operations at Site 300 include four defense program activities: (1) hydrodynamic testing, (2) charged particle beam research, (3) physical, environmental, and dynamic testing, and (4) HE formulation and fabrication. In 1981, environmental investigations began at Site 300. The U.S. Environmental Protection Agency (EPA) evaluated the site using its Hazard Ranking System, and the resulting score of 31.6 caused the site to be named to the EPA National Priorities List (Superfund) in 1990. A Federal Facility Agreement was signed in 1992 and revised in 1997.



Explosives testing at Site 300.

A number of program activities resulted in releases of chemicals to the environment, including:

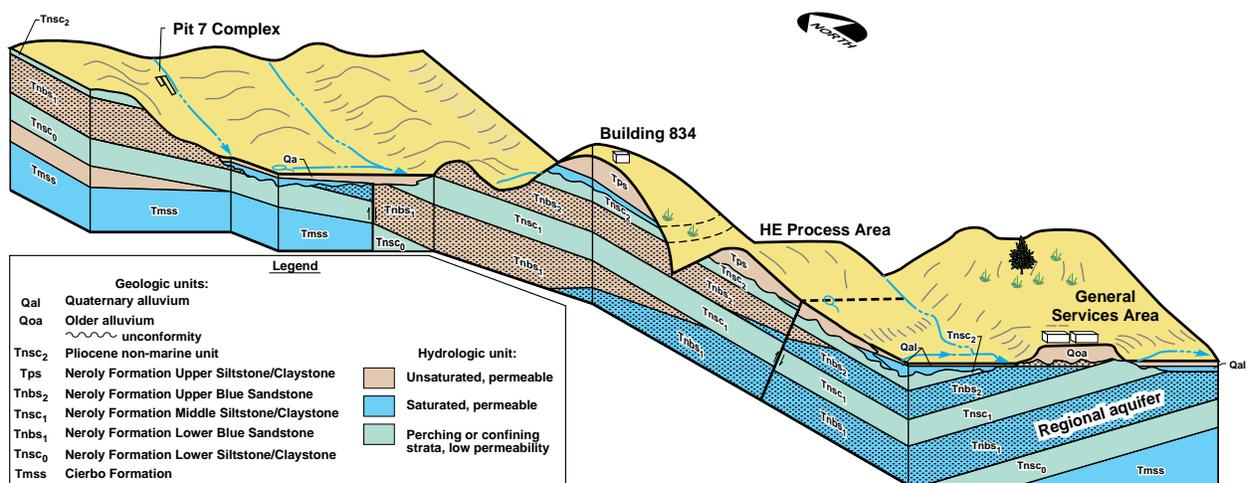
- Disposing of waste fluids in sumps (dry wells).
- Surface spills from drum storage areas.
- Piping leaks from heat exchange systems.
- Burial of contaminated debris in unlined pits, trenches, and landfills.
- Debris and shrapnel scattered or released during HE detonations at firing tables.
- Leaking underground fuel tanks.
- Open burning of HE compounds.
- Discharging contaminated rinse water to unlined lagoons and retention basins.

## Site Conditions

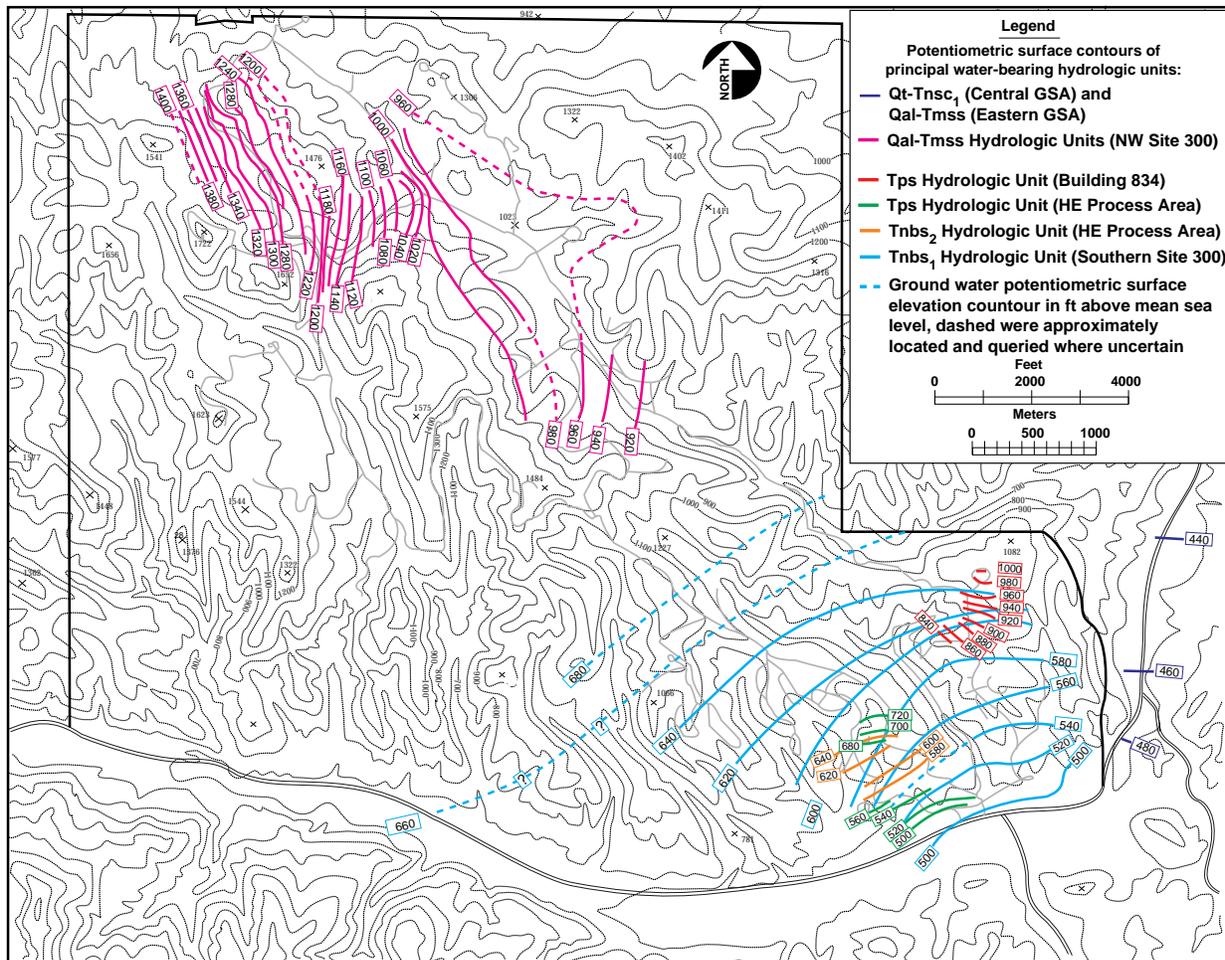
LLNL Site 300 is located 30 miles south-east of San Francisco in the semi-arid Altamont Hills.



The topography is extremely rugged, with up to 1,200 feet of relief. Vegetation consists of seasonal grasses with small trees and bushes at springs and in valleys. Climate is semi-arid with average annual precipitation of 10 in/yr. Potential evapotranspiration is 60 in/yr. There are 20 springs at Site 300, but no permanent surface water drainages. Land north and west of Site 300 is used for cattle grazing and light agriculture. Land to the east is used for these purposes and for a privately-owned explosives test facility. Land to the south is used for ranching and for the Carnegie State Vehicle Recreation Area (SVRA). Ground water provides the properties surrounding Site 300 with potable and stock water. Onsite water needs are currently met by ground water. Beginning in 1998, onsite potable water will be provided by the Hetch-Hetchy aqueduct.



Site 300 hydrogeology is dominated by the Miocene Neroly Formation siltstone, claystone, and sandstone. Thin veneers of colluvium and variably saturated alluvium locally overlay bedrock. Several regional faults transect Site 300 as does a broad northwest-southeast trending anticline. Strata north of the anticline generally dip northeast while strata south of the anticline dip southeast. Ground water flow is often dip controlled.



Many distinct water-bearing zones have been identified at Site 300. Faults, folds, and permeability contrasts influence ground water flow.

## Nature and Extent of Contamination

### General Services Area (GSA) Operable Unit (OU-1)

Contamination has resulted from past solvent disposal, causing VOC contamination of soil, bedrock, and ground water. Two primary ground water plumes have been identified, both extending off site. The central GSA ground water plume emanates from former sumps (dry wells) near Building 875; historic maximum total VOC concentrations in ground water within this plume are on the order of 350,000 micrograms per liter ( $\mu\text{g/L}$ ). Dense Non-Aqueous Phase Liquids (DNAPLs) are present near the release point. The eastern GSA plume originates from a debris trench where solvent-contaminated craft shop waste was buried. Ground water and vadose zone remediation is ongoing.

### Building 834 Operable Unit (OU-2)

Past spills of Trichloroethene (TCE), used as a heat exchange fluid, have resulted in contamination of the vadose zone and a perched water-bearing unit. The deeper regional aquifer has not been affected. The historical maximum total VOC concentration detected in perched ground water is 800,000  $\mu\text{g/L}$ . DNAPLs and Light Non-Aqueous Phase Liquids (LNAPLs) are known to be present. Ground water and vadose zone remediation is ongoing, as is innovative technology development.

### Pit 6 Operable Unit (OU-3)

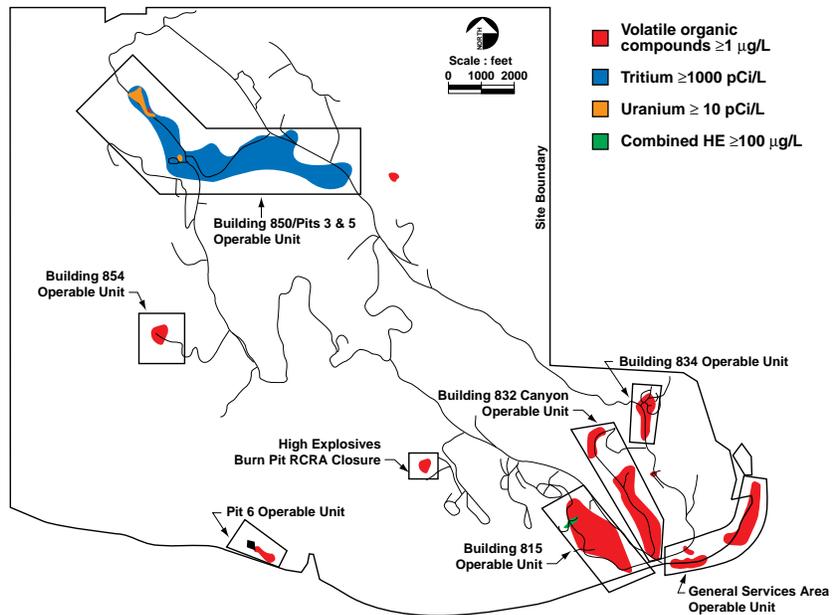
From 1964 to 1973, approximately 1,900 cubic yards of waste was placed in nine unlined debris trenches and animal pits at the Pit 6 Landfill. The material buried included laboratory and shop debris, and biomedical waste. Contaminants potentially associated with the waste include organic solvents, PCBs, metals, and radionuclides. Plumes of VOCs and tritium in ground water emanate from the landfill. The TCE concentration in ground water has been declining since 1989 when the highest concentration measured was 250  $\mu\text{g/L}$ . The maximum concentration of TCE detected in 1997 was 15  $\mu\text{g/L}$ , slightly above the federal and state Maximum Contaminant Level (MCL) of 5  $\mu\text{g/L}$ .

*Operable units and the extent of ground water contamination.*

The maximum activity of tritium currently detected in ground water is 1,540 picocuries per liter (pCi/L), well below the MCL of 20,000 pCi/L. The landfill was capped in 1997.

**HE Process Area Building 815 Operable Unit (OU-4)**

TCE was stored and used at the Building 815 steam plant to clean scale from boilers. Historic maximum total VOC concentrations in ground water are on the order of 150 µg/L. Low concentrations of nitrate and the HE compounds RDX and HMX are also present. Ground water remediation to control plume migration is planned as a removal action.



**Building 850/Pits 3 & 5 Operable Unit (OU-5)**

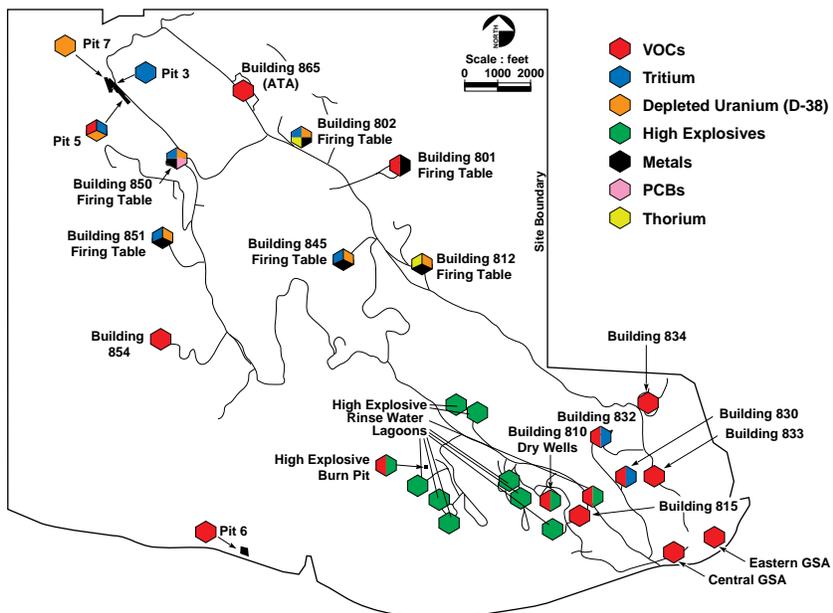
Contamination emanates from the Building 850 firing table, and from landfill Pits 3 and 5. Tritium is the primary contaminant in ground water, at a current maximum tritium activity of about 1,500,000 pCi/L. TCE has been detected downgradient of Pit 5 at concentrations below the MCL. Uranium isotope signatures characteristic of depleted uranium have also been identified, and PCB-bearing shrapnel from explosive experiments is present. A removal action is being evaluated.

**Building 854 Operable Unit (OU-6)**

TCE was used at Building 854 as a heat exchange fluid, and site characterization indicates extensive vadose zone and ground water contamination. The maximum concentration of TCE in ground water is approximately 3,000 µg/L. The need for remediation is being evaluated.

**Building 832 Canyon Operable Unit (OU-7)**

Facilities in the OU were used to test the stability of weapons and weapons components under various environmental conditions and mechanical stresses, and TCE was used as a heat exchange fluid. Contaminants released to the subsurface are primarily VOCs, although tritium, nitrate, and HE compounds were also detected. Vadose zone and ground water contamination was identified associated with both release sites. The maximum TCE concentration in ground water is approximately 15,000 µg/L, and the plume may extend offsite. A treatability study evaluating ground water and soil vapor extraction is underway, and an OU ROD will be obtained.



**Site 300 Operable Unit (OU-8)**

Covers all releases not included any ROD for individual OUs.

*Contaminant release sites.*

## Contaminants of Concern

### VOCs:

Trichloroethylene	(TCE)
Perchloroethylene	(PCE)
1,1 & 1,2-Dichloroethylene	(DCE)
1,1 & 1,2-Dichloroethane	(DCA)
1,1,1-Trichloroethane	(TCA)
Chloroform	
Freon-113	

### HE Compounds:

Cyclo-1,3,5-trimethylene- 2,4,6-trinitramine	(RDX)
Cyclotetramethylene tetranitramine	(HMX)

### Radionuclides:

Tritium	( <sup>3</sup> H)
Depleted uranium	(D-38)
Thorium	(Th)

### Metals:

Aluminum	(Al)
Chromium	(Cr)
Copper	(Cu)
Lead	(Pb)
Vanadium	(Va)
Zinc	(Zn)

### Other chemicals:

Nitrates	(NO <sub>3</sub> )
Polychlorinated Biphenyls	(PCBs)
Oils	

## Site Characterization Methodology

Remedial investigation activities at Site 300 involve geologic mapping, borehole sampling, geophysical logging, well installation followed by ground water elevation measurement and chemical sampling and analysis, hydraulic testing, and regional hydrogeologic analysis. Hydrogeologic cross sections showing stratigraphy, contaminant distribution, and impacted water-bearing zones are constructed using these data. Investigations also include seismic reflection profiles, trenching across known or suspected active faults, ground penetrating radar and magnetic surveys, biotic assays, and aerial photograph analysis.

ER staff use hydrostratigraphic correlation and time-series analysis to define discrete aquifer systems and to determine the influences of recharge and ground water flow on water level response and ground water chemistry. Site characterization activities have utilized data from additional methods, including:

- Active vacuum-induced soil vapor sampling
- Passive soil vapor surveys
- Neutron moisture density logging
- Downhole colloidal borescope (measures *in situ* ground water flow direction and velocity)
  - *In situ* ground water chemical analysis fiber-optic probe
  - Field bioassay kits for soil chemical analysis
  - *In situ* dissolved oxygen measurements
  - Evaluation of stable and non-stable isotopes
  - Flux chamber measurements
  - Cone penetrometer surveys

Once characterization is complete and a conceptual hydrogeologic model developed, contaminant fate and transport mathematical models are applied to calculate estimates of the risk from chemicals released to soil and ground water.



Monitor well installation

## Remediation Plan

The overall long-term environmental remediation strategy for LLNL Site 300 integrates ground water extraction and treatment, source isolation, and hydraulic control based on:

- Detailed characterization, including hydrostratigraphic unit analysis
- Validated contaminant fate and transport modeling
- Ground water and soil vapor extraction and treatment
- Adaptive time-managed pumping
- Innovative technologies testing
- Subsurface interceptor drains and landfill/source capping

## STATUS OF CLEANUP

### Objectives

The objectives of the ER program at Site 300 are to: (1) reduce exposure risk, (2) reduce contaminant mass in soil and ground water, (3) control plume migration, (4) prevent contamination of offsite water-supply wells, and (5) remove active sources. CERCLA Removal Actions have accelerated cleanup prior to the completion of RODs.

### Current Strategy

Operable Unit	Contaminants Present	Cleanup Strategy	Closure Pathway
General Services Area OU	VOCs	Ground water and soil vapor extraction for source control, mass removal, and migration control.	OU Record of Decision (1997).
Building 834 OU	VOCs	Ground water and soil vapor extraction, innovative technologies for mass removal.	OU Interim Record of Decision (1995); Final ROD (2000).
Pit 6 Landfill OU	VOCs, tritium	Landfill capping, considering monitored natural attenuation.	CERCLA removal action to cap landfill (1997), with final remedy selection deferred to Site 300 ROD (2000).
Building 815 OU	VOCs, HE compounds, nitrate	Ground water extraction to prevent further plume migration.	Migration control as a removal action, with final remedy selection deferred to Site 300 ROD (2000).
Building 850/Pits 3 & 5 OU	Tritium, uranium, PCBs, VOCs	Considering monitored natural attenuation of radionuclides and VOCs, engineering controls, and removal of shrapnel containing PCBs.	Removal action, with final remedy selection deferred to Site 300 ROD (2000).
Building 854 OU	VOCs	In characterization phase, but may require ground water and soil vapor extraction.	Undetermined. OU ROD if required.
Building 832 Canyon OU	VOCs, tritium, HE compounds, nitrate	In treatability study phase, evaluating ground water and soil vapor extraction. Also considering a permeable reactive wall.	OU ROD (2001).

### Remediation Completed

Since ER work began in 1981, a number of remedial actions have been completed at Site 300, including:

- Excavating soil contaminated with VOCs at Buildings 834 and 854 (1983)
- Exhuming uranium-contaminated waste buried in the Pit 6 landfill (1971)
- Enhanced soil bioremediation of diesel-contaminated soil (1990-1991)
- Closing eleven HE rinse-water lagoons (1985-1989)
- Closing and excavating numerous waste water disposal sumps (dry wells) (1983-1989)
- RCRA capping of the Pit 1 and 7 landfills (1992)
- CERCLA capping the Pit 6 landfill (1997)
- Removing or replacing gravels contaminated with radionuclides and metals at six HE firing tables (1988-1989)
- Sealing and abandoning four water-supply wells to prevent contamination of drinking water aquifers (1988-1990)

## Remediation Project Profile: General Services Area OU

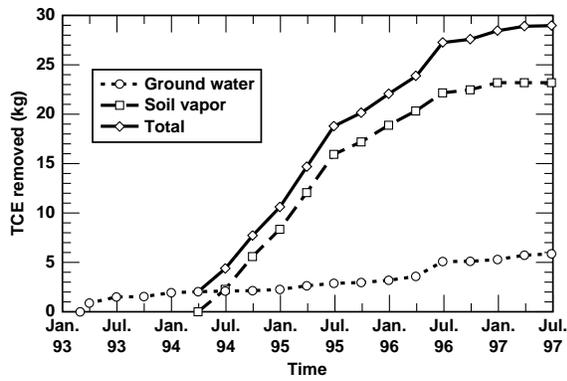
Solvents containing VOCs, primarily TCE, were released to the subsurface as a result of past activities in the craft shops and equipment fabrication and repair facilities. Remediation began in 1991 as a CERCLA removal action. A ROD is in place, and the cleanup has moved into the remedial action phase. The ROD specifies MCLs as the ground water cleanup standards.

DOE/LLNL are currently operating two ground water extraction wellfields and one soil vapor extraction system. The total actual and projected costs for investigation and remediation in the GSA OU are estimated at \$38.6M. Modeling estimates that to meet cleanup standards, soil vapor extraction will need to continue for 10 years, and ground water extraction for 55 years.

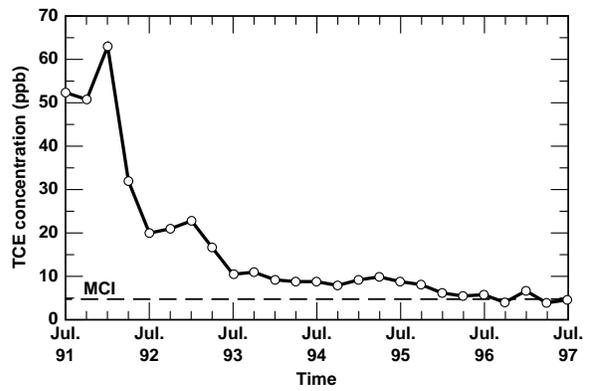
The eastern GSA ground water remediation system was formally designated “Best Project” status in a DOE study of over 500 DOE, Department of Defense, and private sector projects. The eastern GSA was one of only seven nationwide projects to earn this distinction. The evaluation criteria included cost effectiveness, performance, and design.

### Analysis of the Central and Eastern GSA ground water and soil vapor remediation projects.

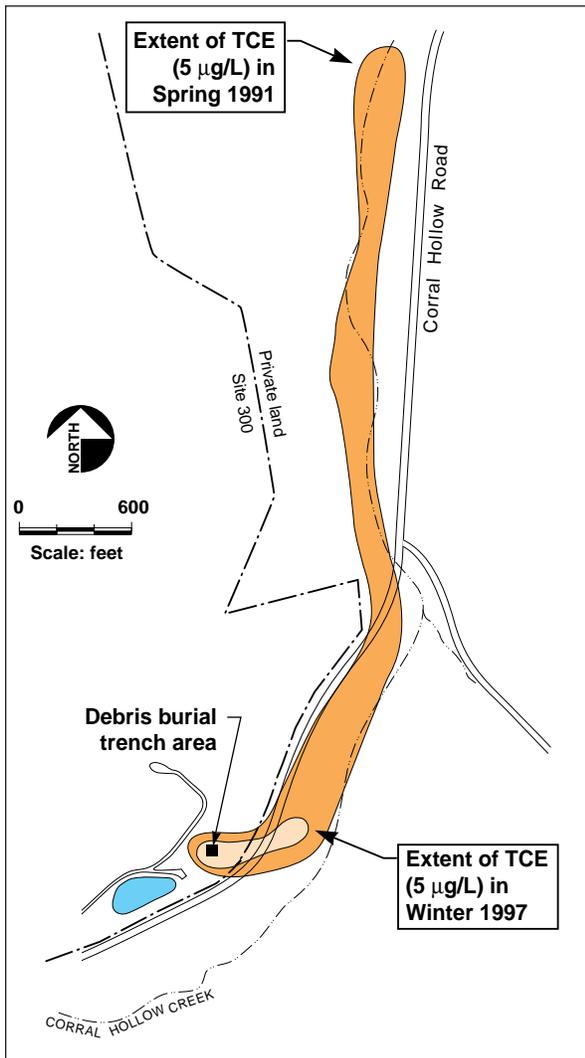
	Central GSA	Eastern GSA
Objective	Source area mass removal and concentration reduction	Migration control, offsite water-supply well protection
Source area	6 dry wells, drum rack, and steam cleaning area	1 buried debris trench
Hydraulic conductivity and well yields	Low conductivity fractured bedrock. Contaminant migration rates are very low. Extraction well yields are less than 1 gallon per minute (gpm).	Very high conductivity. Contaminant migration rates extremely rapid. Extraction well yields are greater than 25 gpm.
Maximum TCE concentration in ground water	Pre-remediation: 240,000 µg/L, with DNAPL present Current: Less than 1,000 µg/L, all in dissolved phase	Pre-remediation: 74 µg/L, all in dissolved phase Current: Approximately 5 µg/L
Quantity of ground water extracted	820,000 gallons (since 1993)	102,000,000 gallons (since 1991)
Maximum TCE concentration in soil vapor	Pre-remediation: Over 1,000 parts per million by volume (ppmv) Current: Less than 2 ppmv	Not applicable
Quantity of TCE extracted	Ground water: 6 kg Soil vapor: 23 kg	Ground water: 5 kg
Performance Assessment	<ol style="list-style-type: none"> <li>1) Remediation has reduced maximum TCE concentration in ground water significantly</li> <li>2) Contaminant concentrations no longer indicate the presence of DNAPL</li> <li>3) Extent of contamination has not been affected. Wellfield expansion will address this issue</li> <li>4) Soil vapor extraction has been more effective in removing mass than ground water extraction.</li> </ol>	<ol style="list-style-type: none"> <li>1) Extent of offsite plume reduced significantly. The extent of the offsite contaminant plume with TCE concentrations above the MCL 5 µg/L has been reduced from 4,750 ft to only 100 ft.</li> <li>2) Maximum TCE concentration reduced to near-MCL levels</li> <li>3) Successfully protects offsite water-supply wells.</li> </ol>



Cumulative mass of TCE removed from ground water and soil vapor at the Central GSA.



TCE concentration in ground water treatment system influent at the eastern GSA.



Eastern GSA pre-remediation and current plume configurations.



Central GSA Portable Treatment Unit (since 1997).

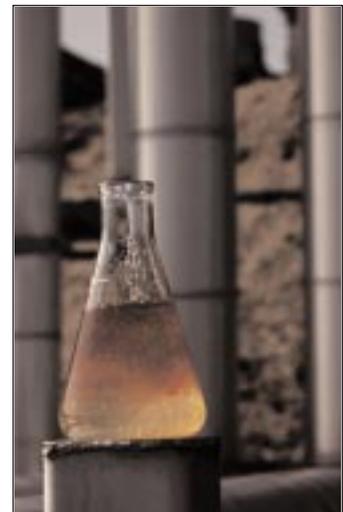
## Remediation Project Profile: Building 834 OU

The Building 834 Complex houses facilities for thermal stress testing of prototype weapons components. The facility contains a control building, three former heat fluid transfer and storage buildings and seven test cells. Past spills of TCE, which was used as a heat exchange fluid, have resulted in soil, bedrock, and ground water contamination. The affected ground water is confined to a perched water-bearing zone; the deeper regional aquifer has not been affected. The historical maximum total VOC concentration detected in perched ground water is 800,000 µg/L. DNAPLs are known to be present. Tetra t-butylorthosilicate (T-BOS, a pump and seal lubricant similar to mineral oil) and diesel fuel contamination are also present as Light Nonaqueous Phase Liquids (LNAPLs).

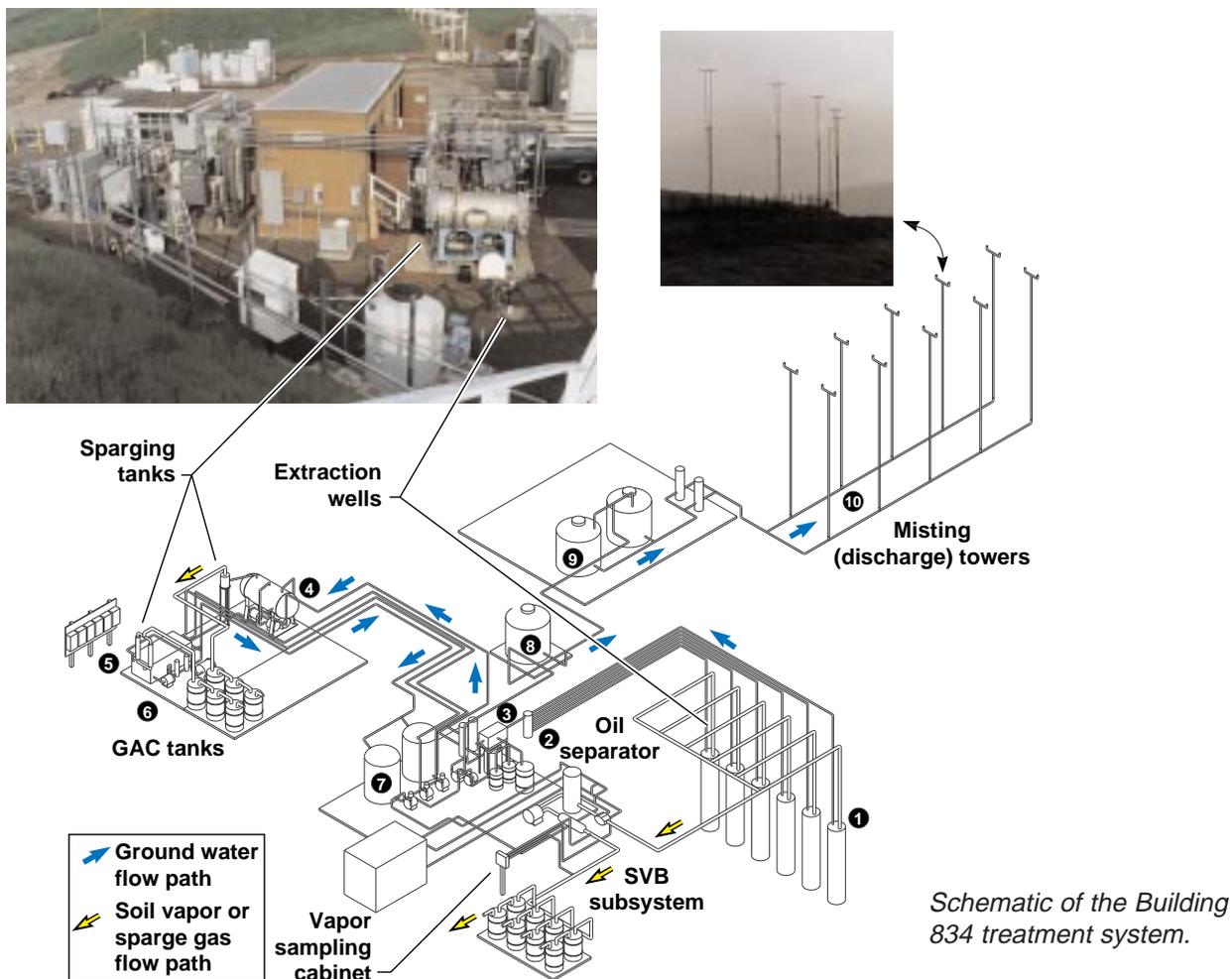
### Project Highlights

- Removal actions using simultaneous soil vapor and ground water extraction were initiated in 1988 to reduce VOC vapor exposure risk and reduce VOC mass in the subsurface.
- To reduce costs, equipment and components were recycled from the original Building 834 Complex heat-exchange system, and from surplus equipment from former LLNL Weapons Program projects.
- The site is equipped with computer-controlled gas analysis equipment for direct and remote monitoring of soil and ground water chemistry; treatment process parameters can also be monitored remotely.
- The modular facility design and well-equipped infrastructure allows testing of new technologies to expedite remediation and reduce the quantity of hazardous wastes generated by remedial activities.
- DOE/LLNL have tested several innovative technologies at Building 834, including the application of electron beam destruction of VOC vapor, and ultraviolet oxidation of TCE using flashlamps.
- An Interim ROD was finalized in September 1995 that allows renewed testing and implementation of innovative remedial technologies for a three year period while continuing the operation of the existing soil vapor and ground water extraction and treatment system.
- In 1997, LLNL collaborated with Oregon State University on using neutral Radon-222 as tracer for locating DNAPLs, evaluating of efficiency of bioremediation of LNAPL and DNAPL, and conducting two surfactant tests to remove DNAPLs from the subsurface.
- In 1998, LLNL will conduct several additional *in situ* treatment technologies, including oxidizing agents and microcosms.

*For more than 20 years, TCE was used as a heat-exchange medium for heating and cooling test cells. Because TCE is an extremely effective solvent, it dried seals and other components in the temperature control system, producing leaks and spills. To retard this action, a synthetic oil, known as T-BOS, was added to the TCE. TCE degradation products are also present (e.g., cis-1,2-DCE).*



*Bailed ground water from Building 834*



The stages of the Building 834 ground water treatment process: (1) ground water extraction using air displacement pumps, (2) oil separation in a coalescing skimmer, (3) particulate removal (to 20 $\mu$ ), (4) primary sparging (5) secondary sparging, (6) T-BOS and residual VOC removal (primarily Freon-113) with woven carbon-impregnated filters, (7) pumping to short-term storage in two 500-gallon stainless steel tanks at the treatment pads, (8) freeze drain storage tank, (9) pre-air misting storage tanks, and (10) discharge of treated ground water by air misting.

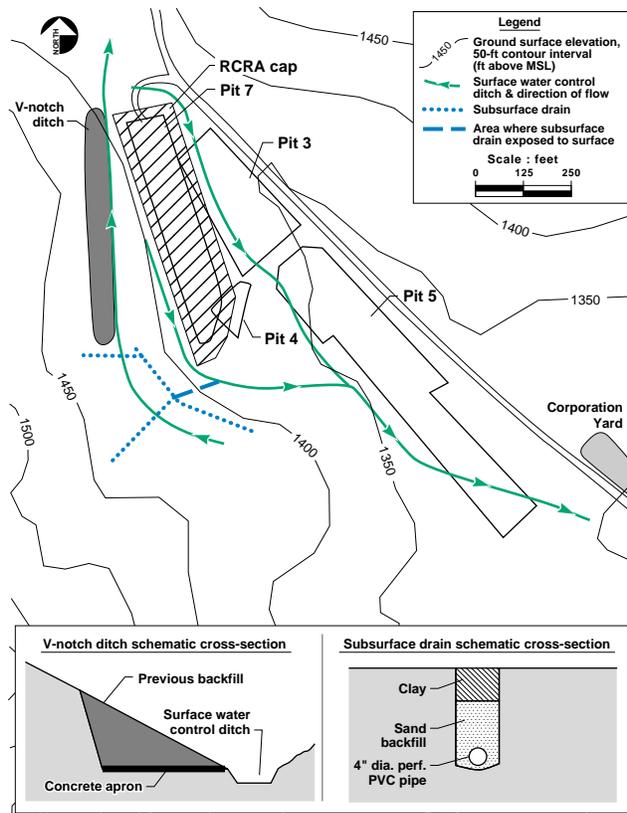
## Remediation Project Profile: East and West Firing Areas

Seven HE testing firing tables, nine landfills (all closed), and a small analytical linear accelerator are located in the East and West Firing Areas. Explosives experiment debris contains tritium, depleted uranium (D-38), metals, and PCBs. No fissile material was used in the experiments. The debris was disposed of in adjacent unlined mixed waste landfills. Two comingling tritium plumes emanate from landfill Pits 3 and 5. Tritium was mobilized during the 1982-83 wet winter from direct infiltration and ground water inundation of the pits. The Building 850 firing table is the source of a third ground water tritium plume. Maximum tritium activities were 1,200,000 pCi/L in water samples collected in 1983; current maxima are about 300,000 pCi/L. Building 850 and Pits 3 and 7 are also release sites of depleted uranium to ground water. Three small plumes exist and the maximum detected total uranium activity is less than 100 pCi/L.

### Project Highlights

- Resource Conservation and Recovery Act (RCRA) caps have been installed on two landfills (Pits 1 and 7). The caps consist of eight feet of natural earth materials, including two feet of compacted low permeability clay. The caps and associated surface and ground water control measures are designed to prevent release of tritium, depleted uranium, barium, lead, beryllium, and other metals from the landfills to the ground water. At Pit 7, DOE/LLNL installed an upgradient interceptor trench to direct recharge water away from the local hydrologic system.

- Conservative ground water modeling indicates that by the time the tritiated ground water reaches the site boundary, tritium activities will be only slightly above background.
- Gravel and soil containing tritium, uranium, and metals from six high explosive firing tables were removed. At three active firing tables, the tritiated gravels were replaced with fresh material.



*Planimetric map of the Pit 7 RCRA cap system and detailed cross sections of key features.*



*Pit 7 RCRA cap and drainage system prior to vegetation seeding.*

## Remediation Project Profile: Pit 6 OU



*Pit 6 landfill cap construction.*

*Installing the liner system.*



From 1964 to 1973, approximately 1,900 cubic yards of waste was placed in nine unlined debris trenches and animal pits at the Pit 6 Landfill. The material buried included

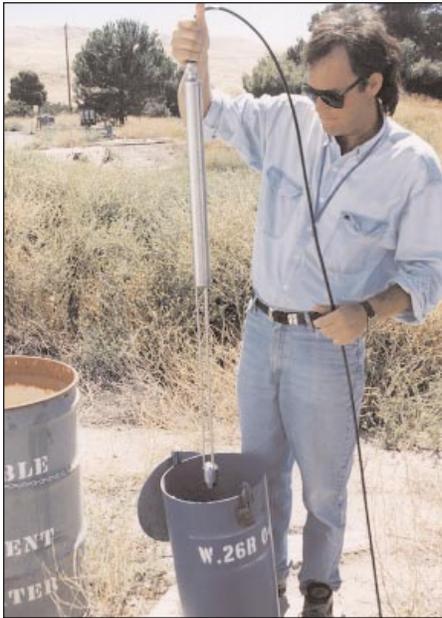
laboratory and shop debris, and biomedical waste. Contaminants potentially associated with the waste include organic solvents, PCBs, metals, and radionuclides. Analyses of ground water, soil vapor, soil, and bedrock indicate that VOCs and tritium have been released from the Pit 6 Landfill. Contamination extends to a depth of about 70 feet, and affects the saturated terrace alluvium and shallow bedrock aquifer. No water-supply wells have been affected, nor has any contamination been detected offsite. Data indicate that TCE emanates from the southeastern part of the landfill, possibly from buried drums. TCE concentration in ground water has been declining since 1989 when the highest concentration measured was 250 µg/L. The maximum concentration of TCE detected in 1997 was 15 µg/L, slightly above the federal and state MCL of 5 µg/L. The maximum activity of tritium currently detected in ground water is 1,540 pCi/L, well below the MCL of 20,000 pCi/L. Disposal records indicate that one shipment cell near the northeastern corner of the landfill received more than 99% of the tritium buried in the landfill and is the most likely source of the tritium contamination.

- In 1997, a 2.4-acre engineered cap was constructed over the landfill as a CERCLA non-time-critical removal action. The objectives of the cap are to: (1) isolate the buried waste from infiltration, (2) divert surface water from the covered area, (3) eliminate safety hazards from subsidence into void spaces in the buried waste, (4) mitigate risk from potential inhalation of vapors from the subsurface, and (5) reduce ground water recharge near the contaminant plumes.
- The total cost of constructing the landfill cap was about \$1,500,000. Selectively substituting geosynthetic for natural materials saved over \$500,000. Total past and projected project costs are approximately \$4,100,000.
- The contents of the trenches and animal pits will remain in place. Rising ground water inundating the waste is unlikely because the water table historically has been at least 15 feet below the bottom of the waste, and the cap and drainage diversion system will reduce recharge by infiltration.

- The Post-Closure Plan establishes: (1) a Detection Monitoring Program to identify future releases, and (2) a Corrective Action Monitoring Program to assess the performance of the landfill cap. Both programs will be periodically evaluated as part of Site 300 CERCLA Five-Year Reviews. Final cleanup standards for ground water will be determined in the forthcoming Site 300 ROD.
- Documents prepared for the Pit 6 OU include the Site-Wide Remedial Investigation report, a Feasibility Study (later redesignated as an Engineering Evaluation/Cost Analysis [EE/CA]), an addendum to the EE/CA, an Action Memorandum, and a Post-Closure Plan.

## OTHER ER PROJECTS

### Colloidal Borescope



The colloidal borescope is a downhole tool capable of directly observing suspended colloidal size particles (1 to 10  $\mu\text{m}$ ) and determining ground water flow velocity and direction in an open borehole or monitor well in real time. LLNL Site 300 is using the borescope to characterize local ground water flow patterns, site monitor wells, and assess the efficiency of ground water extraction wellfields. The LLNL borescope was also used successfully at Sandia National Laboratory in Albuquerque, New Mexico.

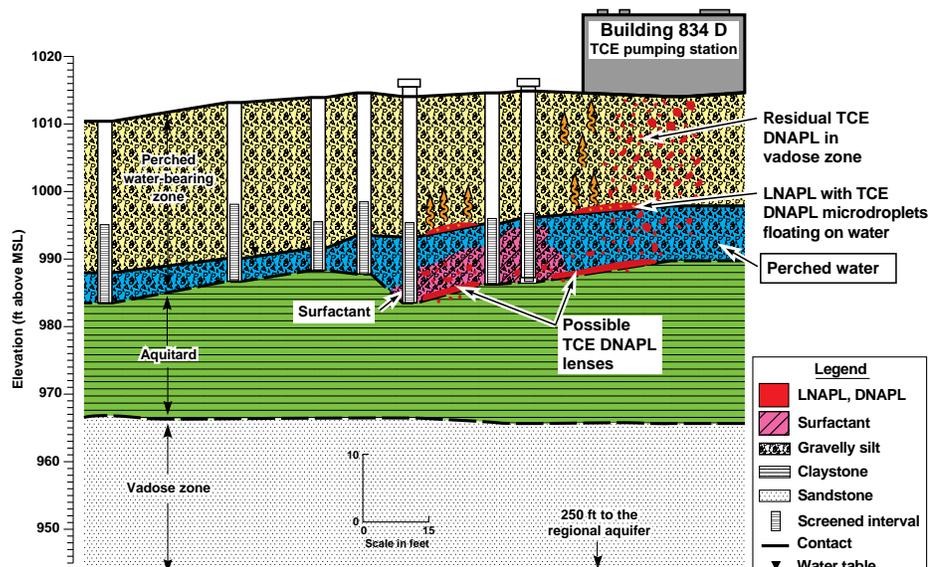
*LLNL is using the colloidal borescope to aid in well placement and to evaluate the progress of ground water remediation.*

### DNAPL Remediation

A major component of the Building 834 OU Interim ROD is applying innovative technologies for the identification, delineation, and remediation of NAPLs. LLNL is demonstrating the application of partitioning tracers to identify and delineate the extent of NAPL contamination in a shallow perched water-bearing zone. Two surfactant injection and extraction demonstration were conducted to solubilize residual NAPL and expedite VOC mass removal at the OU. Other *in situ* technologies including bioremediation and chemical oxidization will also be tested.

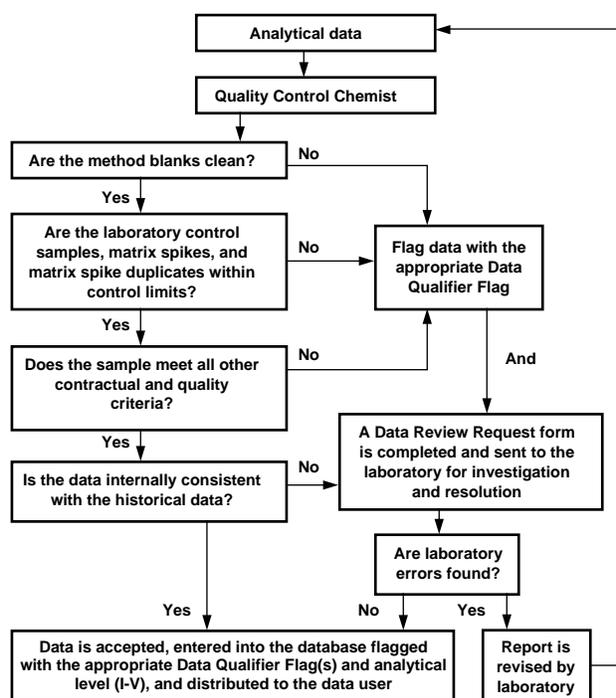
Two surfactant remediation demonstrations for TCE DNAPL contamination in the perched water-bearing zone beneath the Building 834 Complex have been completed. Federal and State regulatory agencies committed their support for innovative technology demonstrations in an Interim ROD for the Building 834 OU.

*Cross section of the Building 834 area.*

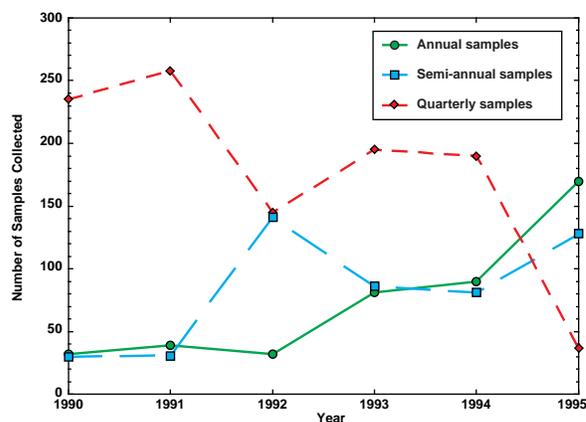


## Sampling

- Site 300 has implemented a sampling, analysis, and data validation program which is both cost-effective and provides data of known and adequate quality.
- Rather than require our contract laboratories to participate in the US EPA's Contract Laboratory Program (CLP), we have implemented a streamlined data-validation procedure (outlined below) which requires our own contract laboratories to provide summaries of their Quality Control (QC) data. This has saved us several hundred dollars per sample in analytical costs without sacrificing data quality.
- Each laboratory's analytical and QC data package can be reviewed by our QC chemists using the streamlined data-validation procedure in less than 15 minutes, rather than several hours required by the CLP. In conjunction with this procedure, we have further reduced data validation time by implementing an electronic data validation program that prepares a report for the QC chemist.
- In addition to reducing analytical costs and data validation time, we developed a Cost-Effective Sampling (CES) algorithm to reduce the ground water sampling frequency without sacrificing data quality or jeopardizing human health or the environment. The CES algorithm permits us to evaluate all available analytical data variability trends with respect to proximity to sensitive receptors. Using this algorithm, we have successfully reduced the percentage of quarterly monitor well samples from almost 80% to about 10%, increased the annual monitor well samples from 10% to 50%, and increased the percentage of semi-annual monitor well samples from 10% to nearly 40%. This integrated sampling, analysis, and data validation program has saved DOE/LLNL several hundred thousand dollars per year while still providing the quality data required to make meaningful remediation decisions.
- The regulatory agencies have recently approved implementing low-volume purging, which will result in significant reductions in sampling and purge water disposal costs.



Streamlined data validation procedure flow chart.



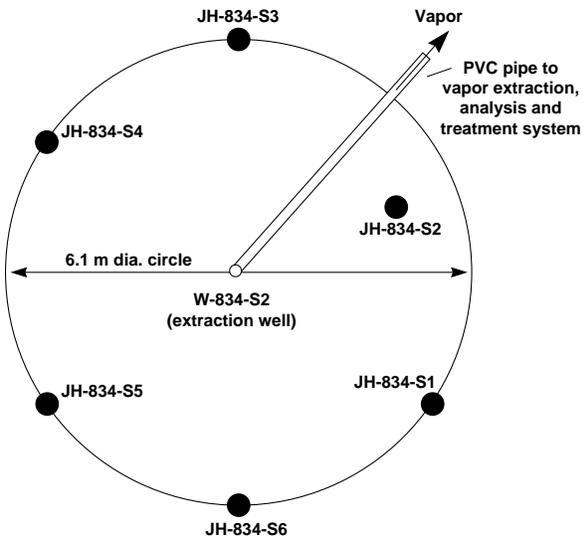
LLNL Site 300 significantly reduced the number of ground water samples collected each year using the Cost-Effective Sampling algorithm, saving several hundreds of thousands of dollars every year.

## VOC UV/Oxidation

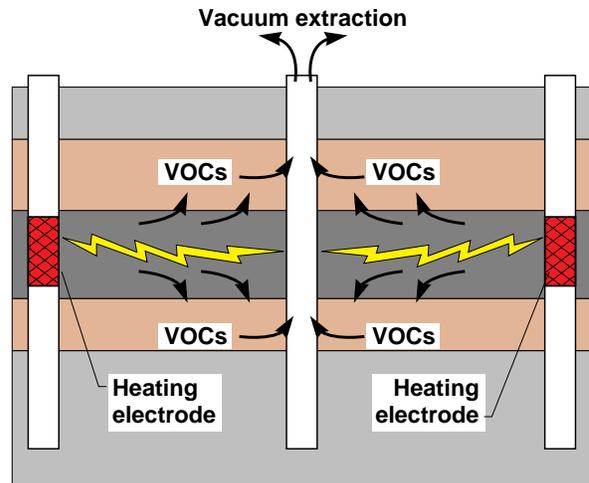
In 1992 LLNL Site 300 was selected by the US EPA SITE Program to demonstrate a full-scale Perox-Pure™ UV/oxidation system. Over a three week period, scientists from LLNL and Perox treated nearly 40,000 gallons of VOC contaminated (primarily TCE) ground water extracted from the central GSA dry well pad area using a chemical oxidation process involving UV light and hydrogen peroxide to oxidize the VOCs. Efficiencies of 99.7% were achieved for the TCE removal and 97.1% for PCE.

## Electrical Heating and Air Stripping

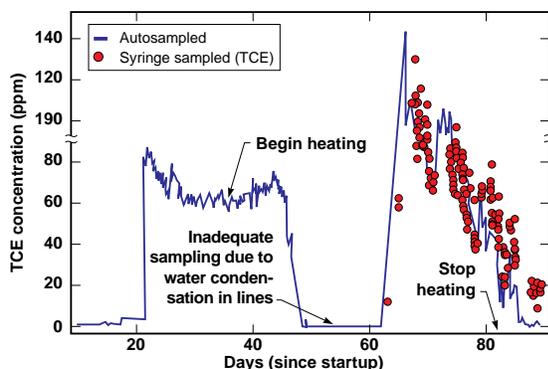
Six electrodes were buried to a depth of 4 meters in a circular pattern with a diameter of 6.1 meters (120 m<sup>3</sup> target volume) to demonstrate the effectiveness of enhanced vapor volatilization in TCE-contaminated soil using 60 hertz ohmic dissipation. Soil vapor was extracted from a single well located at the center of the array. The soil vapor extraction system initially ran for 36 days prior to soil heating. Soil vapor concentrations stabilized at about 60 parts per million by volume (ppmv) when soil heating was initiated. Soil vapor concentrations increased from 60 ppmv to 130 ppmv after 16 days of soil heating and rapidly decreased to about 5 ppmv after 51 days when the demonstration was terminated. Soil vapor temperatures increased from 16°C at the beginning of the demonstration to 38°C at the end. A total of 12 kg of TCE is estimated to have been extracted during this demonstration, requiring a total of 9,600 kilowatt hours (kWhr) (3.46x10<sup>6</sup> joules) of electrical energy.



Field layout of soil heating electrodes (JH-834-S1 through -S6) and soil vapor extraction well (W-834-S2).



Electrical heating volatilizes contaminants in low-permeability soils into more permeable zones where they can be more easily removed by soil vapor extraction.



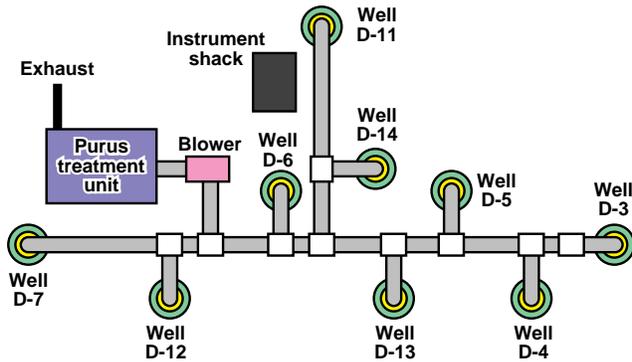
TCE vapor concentrations during the electrical heating demonstration.

## VOC Vapor Destruction Using UV Flashlamp Photo-Oxidation

LLNL Site 300 was selected by the US EPA SITE Program to demonstrate two full-scale xenon UV flashlamp photo-oxidation systems to destroy VOCs in extracted soil vapor. The photo-oxidation systems were tested at flash frequencies of 1 - 30 Hz, temperatures of 33 - 60°C, vapor flow rates up to 300 standard cubic feet per minute (scfm), TCE concentrations up to 10,600 ppmv, and residence times of 5 to 75 seconds.

TCE removal rates greater than 99.9% were achieved in all tests using a flash frequency greater than 1 hertz. Some photo-oxidation byproducts measured during the demonstration were: dichloroacetyl chloride (which further converted

to dichlorocarbonyl [phosgene]), possibly formyl chloride, hydrochloric acid and carbon dioxide. The demonstration was discontinued due to the formation of phosgene; further treatment of the photo-oxidation byproducts is recommended prior to continuing operations.



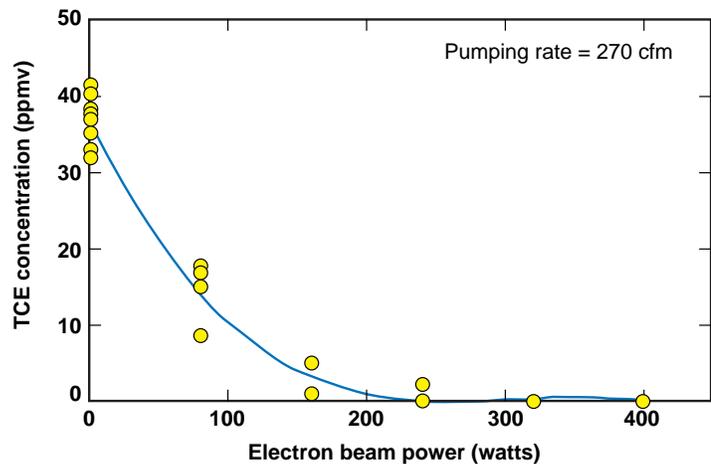
Well ID	Maximum flow rate (scfm)	Maximum TCE concentration (ppmv)
D3	70	420
D4	9	30
D5	15	14
D13	19	19
D14	19	10
D3, D4, D5	23	150
D3, D4, D5, D14	30	100
D13, D14	35	25
All	>250	11

Schematic of UV flashlamp photo-oxidation demonstration.

Maximum vapor flow rates and influent TCE vapor concentrations observed during the UV photo-oxidation demonstration.

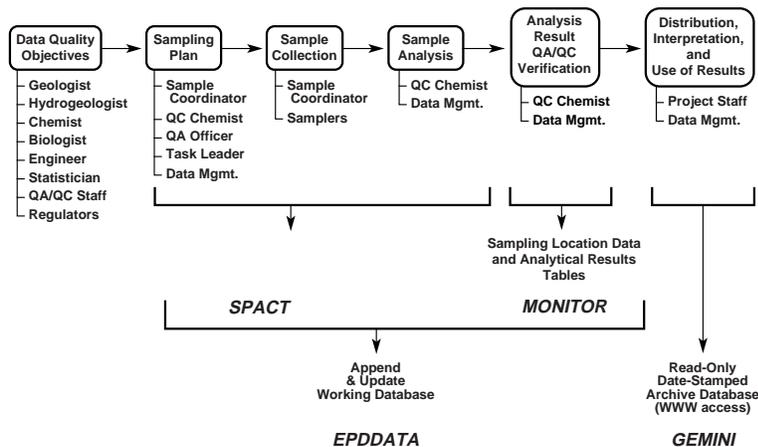
## VOC Vapor Destruction Using Bremsstrahlung Irradiation

The soil vapor extraction system at Building 834 was used to demonstrate the destruction of VOC contaminated vapor effluent using bremsstrahlung irradiation. A 2 MeV electron accelerator with 1 kW maximum beam power was installed in-line with the vapor extraction system. The electron beam accelerator was ramped up at 80 W steps to 400 W, where TCE vapor concentrations were reduced from 40 ppmv to 0.1 ppmv at 270 cfm at 70°F. The resultant dose deposited into the vapor was 88kR. Five reaction products were detected: chloromethane, dichloromethane, chloroform, acetone, and trimethylbenene. Though this test was technically successful, a cost analysis indicated that the technology would be more efficient at concentrations  $\geq 500$  ppm and flow rates  $\geq 500$  cfm.



TCE effluent vapor concentrations at 270 cfm as a function of electron beam power.

## Data and Information Management

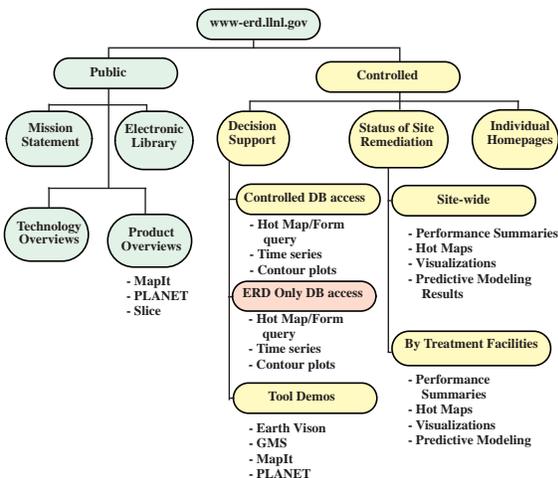


The DMG software tools are linked to the World Wide Web database access, have decreased labor-intensive overhead, and have increased the efficiency of the Ground Water Project.

- The Data and Information Management Group (DMG) of the Environmental Restoration Division at LLNL provides integrated sample and data management services that support planning, collection, tracking, verification, validation, reporting, interpretation and use of data produced in characterization, remediation, self monitoring, and surveillance monitoring.
- This system has been in use at LLNL since 1986. Over 130,000 samples, 1.7 million analytes, and descriptive information, and geographic coordinates, for over 8,800 sampling locations are included in the system. Approximately 2000 sample records are added each month.

## The ERD Web

The LLNL Environmental Restoration Division (ERD) has developed innovative new uses of the emerging World Wide Web (WWW) technology. In addition to the traditional use of providing access to static documents, reports, images, and product and technology overviews, our web-server also provides division personnel and DOE with dynamic access to project status by allowing form-based statistical processing, database access, and cost estimating tools. These new capabilities have demonstrated significant cost savings and, for the first time, have made the enormous amount of collected data available to scientists on their desk top in a timely fashion and in a form immediately useful.



Organization of Environmental Restoration Division World-Wide-Web Server.



LLNL ERD Home Page as shown on the WWW server.

## Regulatory/Institutional Issues

- All treatment facilities comply with San Joaquin Valley Unified Air Pollution Control District standards for VOC releases. Ground water discharges to the Corral Hollow stream channel are also controlled by National Pollution Discharge Elimination System (NPDES) requirements.
- An active and ongoing public involvement program is encouraged through the LLNL Site 300 Community Relations Plan and newsletter.
- An extensive and detailed quantitative risk assessment involving fate and transport modeling of contaminants was performed for LLNL Site 300. Health conservative (reasonable maximum worst case) risk assessment produce cancer risks as high as  $7 \times 10^{-2}$  and Hazards Indices (HIs) as high as 540. These risks exceed the EPA acceptable cancer risk range at Superfund sites and indicate the potential for chronic health effects. No members of the public, or LLNL Site 300 employees are exposed to chemicals at Site 300 at health-threatening concentrations.

- Successful interactions with regulatory agencies include: (1) restructuring and re-negotiating FFA milestones to increase efficiency, reduce costs, and accelerate site cleanup, (2) negotiating reduced reporting requirements, and (3) negotiating low-volume purging prior to monitor well sampling.

## ENVIRONMENTAL RESTORATION SUMMARY

### Accomplishments

- LLNL ground water extraction/treatment remedial and removal actions are significantly reducing offsite plume size, VOC concentrations, and vadose and saturated zone VOC mass.
- Restructuring of CERCLA FFA milestones with State and Federal regulators is leading to reduced costs and accelerated cleanup.
- LLNL designed and constructed treatment systems have successfully removed VOCs in vapor and water by air sparging, carbon adsorption, UV/oxidation, electron beam generated x-ray destruction, and other innovative technologies.
- Several landfills have been successfully capped and closed.
- Cost-effective decision support sampling selection techniques developed at LLNL have resulted in a significant reduction in ground water sampling, analysis, and data management costs.
- Effective use of the WWW allows for rapid access and analysis of data such as contaminant and potentiometric surface trends, data validation, and 3-D viewing of hydrogeological data, which allows decisions to be made in minutes rather than weeks.

### Lessons Learned

- Integration of hydrogeologic data from the various study areas has allowed LLNL to develop a site-wide working hydrogeologic model necessary for targeting specific contaminant plumes, leading to accurate fate and transport modeling, accelerated VOC mass removal, and cleanup optimization.
- Design and application of innovative assessment techniques, some designed at LLNL, have enabled efficient determination of hydrogeology, chemical extent, and risk assessment.
- Advanced ground water and vadose zone fate and transport modeling techniques allowed for in-depth analysis of regulatory cleanup objectives and remedial alternatives.
- Phased implementation of treatment system capacity and the use of modular design was compatible with the need to optimize remedial actions and achieve cleanup objectives.
- Integration of hydrogeologic and engineering design for treatment and waste isolation systems is essential to properly place extraction wells or interceptor trenches and to construct high performance treatment systems in a cost-effective manner.
- Conducting pilot-scale or field treatment tests prior to full-scale construction of ground water treatment systems proved useful and cost effective.
- Remote control techniques for treatment system operations and monitoring, developed at LLNL, can accelerate cleanup and reduce operating costs.
- Open dialogue with regulatory agencies and other Stakeholders has enabled DOE/LLNL to “restructure” the original FFA to accelerate site cleanup by putting the available funds into removal actions at the higher risk areas.
- LLNL Site 300 continues to be an effective testbed for environmental assessment and cleanup technologies.

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